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The energy supply and demand pattern of China: A review of evolution and sustainable development

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ABSTRACT

Energy is the basis of social development. Practices show that national and regional economic development speed and degree are more obviously depending on the construction of modern energy supply support system. As one of the biggest developing countries of the world, the remarkable achievement of China during the last three decades is inseparable with the powerful support for energy. Nevertheless, the limitations of resource distribution and exploitation make the sustainable development of China's energy supply face numerous challenges. This paper reviews the evolution process of China's energy supply and demand pattern, analyzes from two dimensions: time and space, further puts forward the upcoming problems that may occur during the long-term, stable and sustainable development. Finally, several suggestions are proposed from the aspects of matching policy support, structure adjustment and layout optimization, which provide theoretical reference and practical guidance for the comprehensive management of the sustainable energy supply and demand development of China.

Contents

1. Introduction . . . 221
2. The temporal development of energy supply and demand pattern of China . . . 221
 2.1. Energy production . . . 221
  2.1.1. Total energy production analysis . . . 221
  2.1.2. Analysis of the energy production structure . . . 222
  2.1.3. Analysis of concentration ratio of energy supply . . . 223
 2.2. Energy consumption . . . 223
  2.2.1. Analysis of total energy consumption . . . 223
  2.2.2. Analysis of energy consumption structure . . . 223
  2.2.3. Analysis of concentration ratio of energy consumption . . . 224
 2.3. Energy supply & demand co-ordination . . . 224
  2.3.1. Overall analysis of energy supply & demand co-ordination . . . 224
  2.3.2. Analysis of main energy supply & demand coordination . . . 225
  2.3.3. Regional difference analysis of energy supply & demand coordination . . . 225
3. The spatial evolution of China's energy supply & demand pattern . . . 225
 3.1. Analysis of overall energy flow state . . . 226
 3.2. Analysis of average energy transportation distance . . . 226
  3.2.1. Nationwide level . . . 226
  3.2.2. Regional level . . . 226
4. Problems with the sustainable development of China's energy supply & demand . . . 226
 4.1. Critical energy supply & demand contradiction . . . 226
 4.2. Low per capita of energy resource storage . . . 226
 4.3. Imbalanced energy distribution . . . 227
 4.4. Irrational energy consumption structure . . . 227

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5. Suggestions for the sustainable development of China's energy supply and demand 227
5.1. Accelerate transformation of the mode of economic development. 227
5.2. Strengthen energy-saving management system. 227
5.3. Adopt globalized energy resource strategy 227
5.4. Enhance the exploitation and utilization of new energy. 227
5.5. Enhance energy transportation system 227
Acknowledgments. 227
References 228

1. Introduction

The development of the energy industry of any country or region is a procedure of seeking for the coordination between time and space of products' supply security. The procedure of time means the changing trail outlining the total energy demand growing and diverse structure evolution of the country or region; the procedure of space means the expanding process of energy producing range from limited area to the whole region or country, even all over the world [1]. Caiguo and Zhang [2] constructed the theory of temporal and spatial (time–space) coordination process of national industrialization on the base of the interrelation and interaction between the temporal and spatial process in terms of the long-term practice of world's energy security, aiming at proposing policy advises for energy consumption security and sustainable energy development. Zhang Lei [3] also shows that the national energy supply system could extend its spatial bordering as the increasing demands for the fuels, especially oil and gas, due to the uneven distribution of mineral resources of the whole world. Asif and Muneer analyzed four countries, including China, India, UK and USA, to uncover the demand and security issues of energy supply [4]. Yuan Jiahai put forward an outlook of energy demand and supply into 2050 and drafted the roadmap to realize sustainable energy development to set the framing constraints for China's energy policy options [5]. Industrialization practice indicates that, the state of the space–time coordination determines the stability and reliability level of national or regional energy supply security. With the rapid growth of China's total economic scale, it is getting more complicated for coordinating the time and space of national energy supply security. The overall coordination relation is shown in Fig. 1.

Energy supply and demand pattern of a country or region means the situations of energy resources' production, transformation, transportation and consumption within a particular period, and also the circumstances of coordination of energy supply/demand and trans-regional transportation, divided by the variety of the energy and region, of which the “key elements” are the “*gross, structure, layout and flow*” of the supply and demand development of various energy within a period.

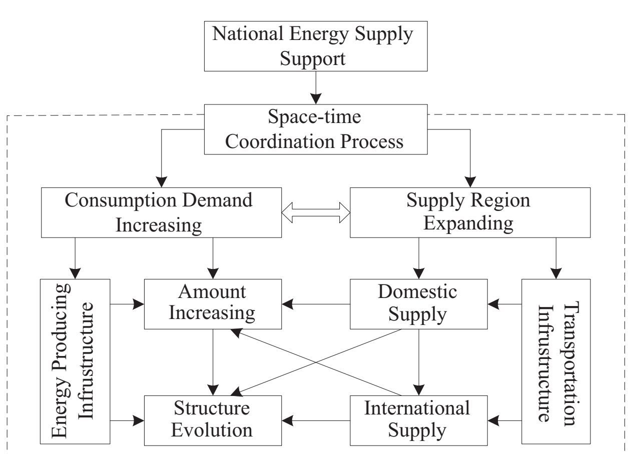


Fig. 1. Temporal–spatial coordination diagram of China's energy supply and demand development.

Since the reform and opening-up of China, the evolution of energy supply and demand pattern is generally expressed as three characteristics [6]: (a) the production, consumption and supply space of energy has greatly increased and expanded with the social and economic development; (b) the spatial expansion process of energy supply is not only the result of the increasing of total energy consumption, but the outcome of consumption structure upgrading, of which the trend of the decline of coal at an absolutely dominant status before and the enhancement of the function of petroleum and natural gas is getting clearer; and (c) Under the joint effect of resource endowment and economic development, the development pattern of energy supply and demand is clearer, of which the elevation of western area's energy output status is of great importance. Therefore, it has profound implications for the stable economic growth and sustainable energy development to thoroughly analyze the space–time feature of China's energy supply and demand development.

The above works to a large extent explained the internal mechanism between energy supply/demand and other influencing factors that determine the coordination of time and space. Besides, they have made a detailed analysis on the current structure of energy supply and demand system. However, shortcomings still exist in these researches. First, some researches fail to relate the energy supply and demand pattern to the overall circumstances of China's energy policy; second, previous reviews focused only on fossil fuel based energy and ignored other important factors including renewable energy sources [7]; third, the energy transportation system has not yet been formally introduced, which is an important part in the current energy supply and demand system of China. This paper focuses on the “pattern” of energy supply and demand of China. The temporal evolution process of energy supply and demand during 1970–2010 is presented, from aspects of energy production and consumption structures; the energy flow situation is especially emphasized in the study of the spatial development of energy supply and demand pattern, where the transport distance is calculated from the angles of nation and region respectively. In the last part, the issues and problems of energy uncovered during the development are analyzed, and accordingly, the suggestions for optimizing the energy policies are proposed to enhance the sustainable development of energy supply and demand.

2. The temporal development of energy supply and demand pattern of China

2.1. Energy production

2.1.1. Total energy production analysis

Since the year of 1978, the total production of primary energy resources has been rapidly increasing, from 0.637 billion ton of

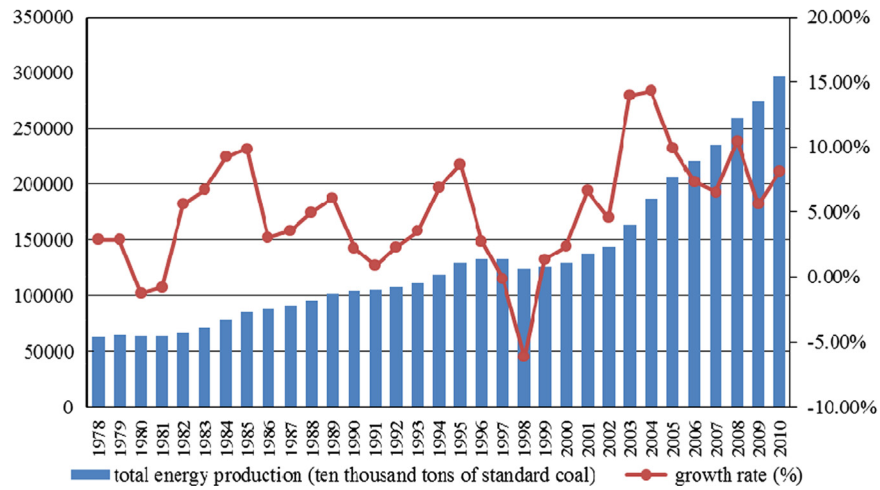


Fig. 2. Annual total energy production amount of China from 1978 to 2010.
Source: China Static Yearbook 2011 [8].

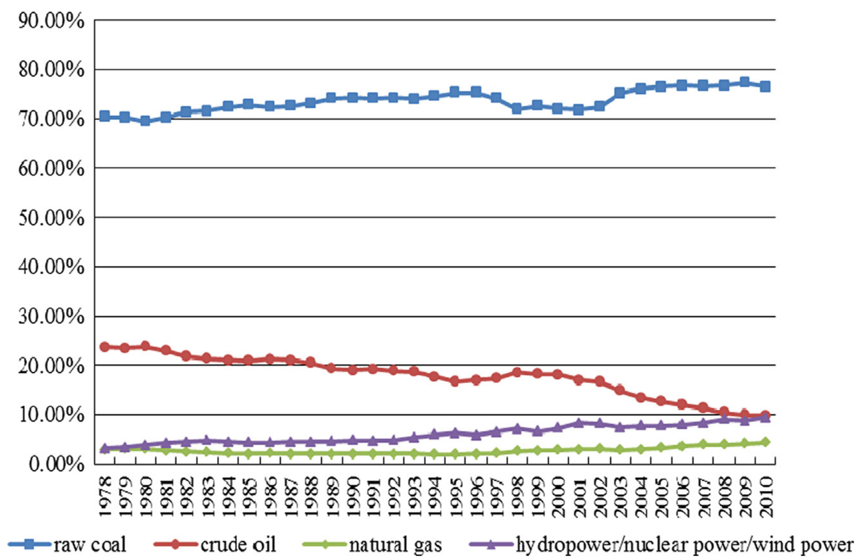


Fig. 3. The primary energy production structure of China from 1978 to 2010.
Source: China Static Yearbook 2011 [8].

standard coal in 1980 to 2.969 billion ton of standard coal in 2010, with an annual growth rate of 4.98%. The yearly total energy production amount and growing situation are shown in Fig. 2.

Specifically, the process of China's energy production can be divided into three stages:

(a) From 1978 to 1995, the growth rate of China's energy production was relatively smooth. Except the years of 1980 and 1981 with a negative growth, the growth rate of the rest years had been maintained between 3% and 7%. The annual growth rate of total energy production amount was 4.3%.
(b) From 1996 to 2002, influenced by the Asian financial crisis and the reform of state-owned enterprises, the economic growth of China severely slowed down. The energy production was also influenced to some extent and the annual growth rate was only 1.6%. In 1997 and 1998, the total energy production amount decreased by 0.2% and 6.2% respectively [9].
(c) From 2003 to 2010, as China was stepping into the middle of industrialization and its economy kept a fast growth rate, the tendency of the primary energy production was ascending, with an annual growth rate of 8.12% of the total production amount.

2.1.2. Analysis of the energy production structure

The amount of energy production has been increasing in recent years. From the production structure of the primary energy, coal is the main force of energy supply all the time, the yield of which increased from 0.44 billion ton of standard coal in 1978 to 2.271 billion ton of standard coal in 2010, with an annual growth rate of 5.25%; petroleum as another main energy resources of China's energy supply, increased relatively more slowly in production, from 0.149 billion ton of standard coal in 1978 to 0.291 billion ton of standard coal in 2010, with an annual growth rate of 2.1%; the yield of natural gas increased from 18.2 million ton of standard coal in 1978 to 0.128 billion ton of standard coal in 2010, with a rapid annual growth rate of 6.28%; hydropower as high-quality and clean energy resources increased the fastest of all, from less than 20 million ton of standard coal in 1978 to 0.279 billion ton of standard coal in 2010, with an annual growth rate of 8.68% [10]. The variation of China's energy production structure is shown in Fig. 3.

From the tendency of the variation of total energy production structure, the yield of coal and new energy are increasing, while petroleum is declining and the natural gas is rising after falling.

Table 1
Supply concentration ratio of China's primary energy sources during 1990–2010; Unit: %.

Energy Sources	Indexes	1990	1995	2000	2005	2010
Raw coal	Amount concentration ratio	58.3	56.5	45.2	58.54	69.47
	Area concentration ratio	11.6	11.6	18.8	18.7	19.68
	Spatial convergence coefficient	5	4.9	2.4	3.13	3.53
Crude oil	Amount concentration ratio	85.9	80.9	77.5	72.72	77.33
	Area concentration ratio	26.5	26.7	26.7	25.98	25.98
	Spatial convergence coefficient	3.2	3	2.9	2.8	2.98
Natural gas	Amount concentration ratio	65.2	60.1	76.3	78.85	89.15
	Area concentration ratio	10.4	25.7	29.5	31.14	33.94
	Spatial convergence coefficient	6.3	2.3	2.6	2.53	2.63
Hydropower	Amount concentration ratio	43.5	45.7	45.3	59.15	59.16
	Area concentration ratio	16.5	11.5	11.5	14.55	15.72
	Spatial convergence coefficient	2.6	4	3.9	4.07	3.76

The main reasons for the changing of the four main primary energy resources can be concluded as

(a) From 1978 to 1995, under guidance of energy policy of “grounding on coal, proactively exploiting petroleum and natural gas, greatly developing hydropower”, the yield of coal and new energy resources had been steadily increasing. The energy production structure adjusted from 70.3:23.7:2.9:3.1 in 1978 to 75.3:16.6:1.9:6.2 in 1995.
(b) From 1996 to 2002, China started to focus on adjusting energy production and consumption structure, requesting enhancing the exploration and exploitation of petroleum and natural gas, and proactively developing new energy. Under such policy environment, the proportion of coal started to decline, while natural gas and new energy steadily increased. Until 2002, the energy production structure of China was 72.3:16.6:3.0:8.1.
(c) From 2002 to present, the energy demand presents the fast growth the tendency. To ensure energy supply, the proportion of coal production has been increasing rapidly, and the proportion of natural gas and new energy still is rising. Until 2010, the energy production structure of China has adjusted to 76.5:9.8:4.3:9.4.

2.1.3. Analysis of concentration ratio of energy supply

Though China has huge energy reserves, its directional distribution is quite uneven, and the geographical distribution of energy production and consumption of each region are extremely unbalanced. Midwest China has plenty reserves of resources, but its regional development has lagged behind, and its transportation is inconvenient; East China has less resources, but it has a huge market demand and its transportation condition is much better; the resources distribution of North China is comparatively centralized, while South China has small and scattered resources distribution, in spite of its huge demand. Therefore, the pattern of *transferring coal from the West to the East* and *from the North to the South* is formed [11]. Besides, the west has abundant resources of water, natural gas and biomass. With the implementation of the *West–East natural gas transmission project*, the west will be the major source of China's natural gas supply. The concentration ratio of the main energy supply is shown in Table 1, and the meaning of each index is as follows:

(a) Amount concentration ratio of energy supply: the proportion of the first five provinces' total production in the national total production of energy supply during a specific period.
(b) Area concentration ratio of energy supply: the proportion of the first five provinces' area in the national total area of energy supply during a specific period.
(c) Spatial convergence coefficient of energy supply: the ratio of amount concentration ratio to area concentration ratio.

2.2. Energy consumption

2.2.1. Analysis of total energy consumption

Since the extensive industrialization in the 1950s, the energy consumption level of China has been increasing and the energy consumption gross been rapidly growing, from 0.57 billion ton of standard coal in 1957 to 3.25 billion ton of standard coal in 2010, with an annual growth rate of 5.59%. The annual energy consumption gross of China is shown in Fig. 4.

Specifically, the process of China's energy consumption can be divided into three stages:

(a) From 1978 to 1996, the growth rate of China's energy production was relatively smooth, and the annual growth rate of energy consumption gross was 4.9%, obviously faster than the growth rate of energy production.
(b) From 1997 to 2002, influenced by the Asian financial crisis and the reform of state-owned enterprises, the economic growth of China severely slowed down. The energy consumption was also influenced with an annual growth rate of 3.24%, slower than the growth rate of energy production.
(c) From 2003 to 2010, as the structure of national economy presents heavy-industrialization and high energy consuming industries develop rapidly, the annual growth rate of energy consumption keeps a high level of 7.4%.

2.2.2. Analysis of energy consumption structure

From the structure of energy consumption, coal is also the main force of energy consumption all the time, the total consumption of which increased from 0.4 billion ton of standard coal in 1978 to 2.21 billion ton of standard coal in 2010, with an annual growth rate of 5.5%, but its proportion in the total energy consumption declines from 95% in the early days of foundation to 68% in 2010, much higher than that of the world's average level, which is 29.3%. The total petroleum consumption increased from 0.13 billion ton of standard coal in 1978 to 0.62 billion ton of standard coal in 2010, with an annual growth rate of 5.0%; the total consumption of natural gas increased from 18.29 million ton of standard coal in 1978 to 0.143 billion ton of standard coal in 2010, with an annual growth rate of 6.6%; hydropower, nuclear power and wind power as high-quality and clean energy resources increased the fastest of all, from less than 20 million ton of standard coal in 1978 to 0.28 billion ton of standard coal in 2010, with an annual growth rate of 8.7%. The variation of China's energy consumption structure is shown in Fig. 5.

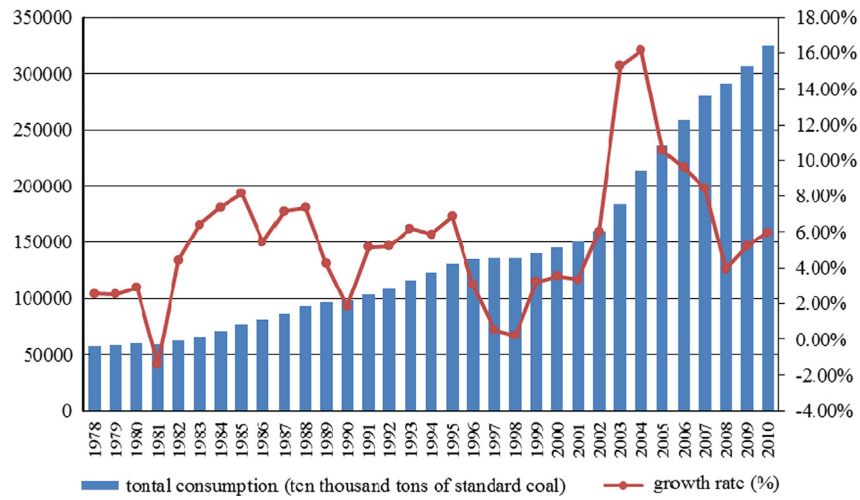


Fig. 4. Annual energy consumption gross of China from 1978 to 2010.
Source: China Static Yearbook 2011 [8].

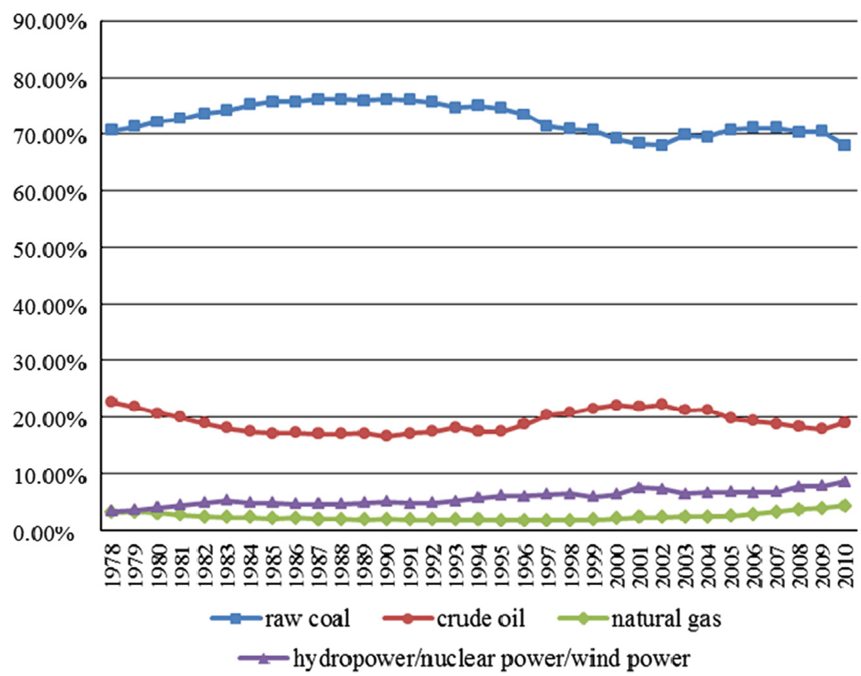


Fig. 5. The primary energy consumption structure of China from 1978 to 2010.
Source: China Static Yearbook 2011 [8].

From the tendency of the variation of total energy consumption structure, the proportion of coal consumption is gradually declining, and petroleum is declining in the recent years, while petroleum is rising after falling and new energy steadily increasing. Influence by national energy policy, macro-environment, economic development and many other facts, the overall consumption structure of coal, petroleum, natural gas and new energy (including hydropower, nuclear power and wind power) has adjusted, from 70.7:22.7:3.2:3.4 in 1978 to 74.6:17.5:1.8:6.1 in 1995, and from 68.0:22.3:2.4:7.3 in 2002 to 68.0:19.0:4.4:8.6 in 2010. So it can be seen that the proportion of new energy consumption increases obviously.

2.2.3. Analysis of concentration ratio of energy consumption

As China stretches across a vast area, each area has distinct differences in economic foundation, industry structure and technical level. Energy consumption concentrates in the east coastal area with more developed economic and centralized industry, where Beijing, Tianjin, Jiangsu, Shandong, Shanghai, Zhejiang, Guangdong are the centers of China's energy consumption. Meanwhile, the increase of energy consumption presents obvious area differentiation. From 1995 to 2008, the total energy consumption of China increased by 1.538 billion ton of standard coal, of which the total energy consumption of Guangdong province increased by 0.231 billion ton of standard coal, accounting for 15% of the national energy consumption [12]. The concentration ratio of the main primary energy consumption is shown in Table 2.

2.3. Energy supply & demand co-ordination

2.3.1. Overall analysis of energy supply & demand co-ordination

China has considerable gross of energy resources covering almost all varieties, including coal, petroleum, natural gas, uranium and all

kinds of other fuel minerals and plenty hydroenergy. The total recoverable reserves of fossil energy (coal, petroleum and natural gas) reaches 21.12 billion ton of standard coal, accounting for 14.9% of the world's amount, and hydroenergy ranks the first in the world. However, with the rapid development of economy, the energy supply & demand could not realize balance only by domestic production and marketing since 1992, and its depending on international import has been rising [13]. The energy supply & demand co-ordination of China is shown in Fig. 6, where DPS means the difference between the volume of production and sales.

Table 2
Consumption concentration ratio of China's primary energy sources during 1990–2010; Unit: %.
Source: China Static Yearbook 2011 [8].

Energy sources	Indexes	1990	1995	2000	2005	2010
Raw coal	Amount concentration ratio	31.4	32.6	44.1	46.6	39.0
	Area concentration ratio	10.9	10.9	7.8	7.8	19.0
	Spatial convergence coefficient	2.9	3.0	5.6	5.9	2.01
Petroleum	Amount concentration ratio	26.2	35.4	45.8	71.4	51.0
	Area concentration ratio	9.3	10.2	10.7	6.1	7.0
	Spatial convergence coefficient	2.8	3.5	4.3	11.8	7.15
Hydropower	Amount concentration ratio	63.0	57.1	62.1	66.0	42.0
	Area concentration ratio	12.2	9.8	14.1	13.9	25.0
	Spatial convergence coefficient	5.2	5.8	4.4	4.8	1.63

2.3.2. Analysis of main energy supply & demand coordination

From different kinds of energy resources, the main energy resources in the energy supply & demand structure of China are coal, petroleum, natural gas and hydropower. In the supply & demand coordination development of each energy source, unified allocation is necessary except international import [14–16]. The main primary energy supply & demand coordination is shown in Table 3.

2.3.3. Regional difference analysis of energy supply & demand coordination

Because of the difference of resource endowment and economic development among different areas, where exists the imbalance of energy supply & demand. In energy production, the pattern shows a successive decline from the west, the middle to the east, while in energy consumption the pattern is reversed [17]. The energy supply & demand coordination of the East, Mid and West China is shown in Table 4.

From the supply & demand coordination of these regions, the imbalance level of China's regional energy production and consumption is getting highlighted. The allocation scale of energy has been expanding in the three areas, forming the state that mid and west area greatly support the development of east area, after satisfying its own demand [18].

3. The spatial evolution of China's energy supply & demand pattern

With the increase of social demand and the improvement of quality of energy, the energy supply support expands its moving space continuously, which leads to the spatial evolution of energy

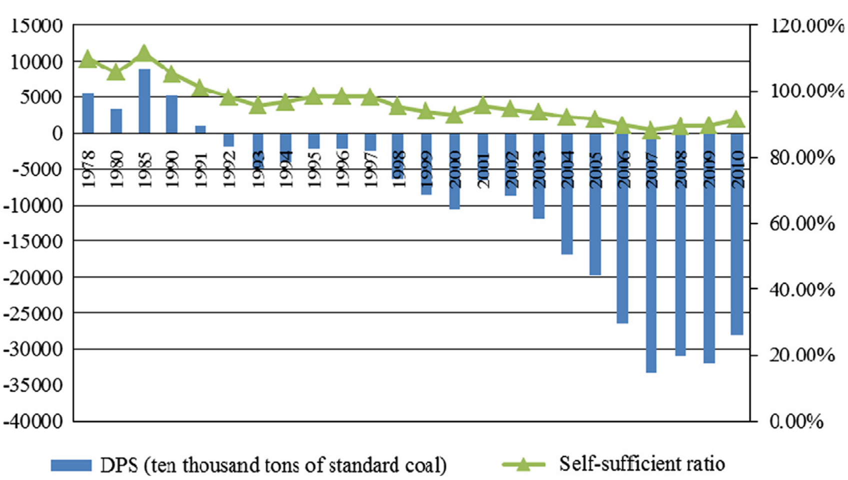


Fig. 6. Energy supply & demand coordination of China from 1978 to 2010.
Source: China Static Yearbook 2011 [8].

Table 3
Supply & demand coordination of the main primary energy during 1980–2010; Unit: ten thousand tons of standard coal; %.
Source: China Static Yearbook 2011 [8].

Energy resources	**Indexes**	1980	1985	1990	1995	2000	2005	2010
Coal	DPS	714	4153	1898	−695	−1070	2240	6182
	Self-sufficient ratio	101.6	107.1	102.5	99.3	98.9	101.4	103.8
Petroleum	DPS	2692	4766	3360	−1536	−8878	−21201	−32641
	Self-sufficient ratio	121.6	136.4	120.5	93.3	72.4	55.1	47.1
Natural gas	DPS	44	24	6	90	355	297	−1530
	Self-sufficient ratio	102.3	101.4	100.3	103.8	110.9	104.7	89.3
Hydropower, nuclear power and wind power	DPS	11	−79	−46	−2	5	−100	−35
	Self-sufficient ratio	100.5	97.9	99.1	100	100.1	99.4	99.9

Table 4
Supply & demand coordination of the three major regions of China during 1995–2010; Unit: ten thousand tons of standard coal; %.
Source: China Static Yearbook 2011 [8].

Regions	Indexes	1995	2000	2005	2010
East	Production	34,184	35,934	40,404	45,736
	Consumption	60,796	68,554	111,767	188,974
	DPS	−26,612	−32,620	−71,363	−130,778
	Self-sufficient ratio	56.2	52.4	36.1	24.2
Middle	Production	66,424	56,585	93,429	99,946
	Consumption	42,934	38,147	58,730	103,857
	DPS	23,490	18,438	34,699	3942
	Self-sufficient ratio	154.7	148.3	159.1	96.2
West	Production	28,425	36,459	72,043	132,789
	Consumption	27,446	31,852	54,185	96,680
	DPS	979	4607	17,858	40,297
	Self-sufficient ratio	103.6	114.5	133	137.3

supply & demand pattern. The evolution mainly embodies in the flow status of energy resources and average transportation distance.

3.1. Analysis of overall energy flow state

From the regional energy resources distribution and energy demand, the east coastal area of China is more developed in economy and is in huge demand for energy, while short of energy resources; the mid–west area is less developed in economy and has less energy demand, but with abundant energy resources. Therefore, a "reverse distribution" is formed in the space of energy production and consumption [9].

From the pattern of the main primary energy production and consumption, the west of China is the main demand center of coal, while the mid–west is the main production center, thus a pattern of "*supplying coal for the East from the Mid–West*" is formed; the overall petroleum consumption exceeds production, which means petroleum be allocated to each region. The amount of allocated petroleum is much bigger in the east and middle areas, and the pattern of petroleum flow in the future of "*transport petroleum from the North to the South and from the West to the East*" is formed [16]; According to the feature of the distribution of natural gas, four main natural gas bases will be built in the future, i.e., Northwest, Southwest, Northeast and Sea area, and the overall future flow will be "*transport natural gas from the West to the East, from the North to the South, offshore gas landing and supplying nearby*" [15]; As for the new energy power generation, large-scale coal power, hydropower and wind power bases will be built in the west area and north area with abundant energy resources, to transmit electricity to the load center in the mid–east area, and the basic electric flow of "*transmit electricity from the West to the East and from the North to the South*" will be formed [19–21].

3.2. Analysis of average energy transportation distance

3.2.1. Nationwide level

In general, under the joint effect of increasing energy consumption demand and expanding resources flow scale, the average energy transportation distance has been obviously extended with the extensive construction of transport infrastructure and exploitation of energy resources. The supply radius of mineral fuel has developed from 400 km in 1980 to 2000 km today.

Considering the main energy, as the main body of primary energy supply, coal plays a crucial role in the extending process of the whole country's energy flow radius. In 1980, the radius of China's primary energy supply was 401 km, of which crude oil owned the longest supply radius, which was 986 km; the supply radius of coal took the second place, which was 291 km; natural gas was the shortest, which was 86 km. As the energy consumption structure has changed greatly, the extending process of primary energy supply is influenced. In 2006, the radius of primary energy supply reached 1766 km, four times of that of in 1980. The supply radius of crude oil still took the first place, which was 6089 km; natural gas took the place of coal, the supply radius of which reached 1439 km; coal had the shortest supply radius, which was 448 km.

Table 5
Average transportation variation of the three main regions' energy supply of China.
Source: China Static Yearbook 2011 [8].

Year	East	Middle	West	Nationwide
Average transportation distance (km)				
1980	526	281	260	401
1995	1151	759	293	930
2006	2189	1258	631	1766
Variation range of transportation distance (km)				
1980–1995	625	478	33	529
1995–2006	1038	499	338	836

3.2.2. Regional level

As the continuous growth of each region's total energy demand and the variation of consumption structure, the energy supply radius increases year by year. The average transportation variation of each region's energy supply is shown in Table 5.

It can be seen from the above table that the average transportation distance of the three regions increases to different extents, where the west has the least average transportation distance and less variation range, while the east has obvious change and high growth rate.

4. Problems with the sustainable development of China's energy supply & demand

4.1. Critical energy supply & demand contradiction

Since reform and opening-up, China keeps a high speed of economic growth, and the energy consumption has increased from 0.57 billion ton of standard coal to 3.25 billion ton of standard coal. According to the estimation, China will be in the "double quick" period of development of industrialization and urbanization before 2020, in the "stable and quick" period of development of a stable industrialization and fast-moving urbanization during 2020–2030. The total energy demand of China will be 4.3/5.2/6.3 billion ton of standard coal in 2020/2030/2050. Although the technologies of energy exploration and exploitation are progressing and the energy production gross is rising, the average growth level is lower than the growth rate of energy consumption. The gap between energy supply and demand has reached 0.35 billion - ton of standard coal until 2010, and the difference between the two continues to widen year by year [22]. Thus, the energy supply & demand contradiction of China is obvious.

4.2. Low per capita of energy resource storage

Population and energy reserves are factors that must be balanced in measuring the level of the nation's energy richness. Although the proven recoverable energy mineral reserves of China accounts for 11% of the world's total reserves and ranks No.3, and the water resource ranks the first place, the per capita is far below the world's average level. For example, the reserves of coal ranks

the third of the world, while the per capita is only 460 ton; the reserves of natural gas ranks 15th of the world, while the per capita is only 4.5% of the world's average level, making the per capital rank 136th in the world [23]. With such a large population, the low per capita of energy resources storage will be a crucial problem in the sustainable development of energy supply & demand.

4.3. Imbalanced energy distribution

Energy resources of China are widely distributed but extremely uneven. With the rapid economic development, the demand of economically-developed regions will be further increasing in a large scale. The "reverse distribution" of the energy supply & demand is much more serious, which determines that the long distance and trans-regional of energy allocation are inevitable. To *transport the coal from the North to the South, transport the petroleum from the North to the South, transport natural gas from the West to the East and transport electricity from the West to the East* in large scale and long distance is the basic pattern of energy flow and transportation, and the energy transport, consumption and cost of which brings big problems in the sustainable development of energy supply & demand.

4.4. Irrational energy consumption structure

Compared with the main countries of the world, China highlights in the coal-based structure of energy consumption. Currently, the proportion of coal in the consumption structure of primary energy runs up to 60%, much higher than the world average, reflecting a heavy dependence on non-renewable fossil energy for the development of the economic society. Although China is enhancing the exploitation and introduction of clean and high-quality energy, the proportion of coal in the primary energy will still remain around 57% in 2020, decline to around 52% in 2030, and decline to around 43% in 2050, great disparity still exists with the current world average [23]. The coal-based energy structure is not conducive for improving energy efficiency, controlling pollution and the greenhouse gas emission, and also is insufficient for the growing demand of high-quality energy of the development of economic society. The large-scale utilization of new energy and renewable energy of China faces the constraints of resources, technology, environment and economic efficiency, while plenty of risks exist using external high-quality energy. Therefore, the optimization of energy structure faces huge challenges.

5. Suggestions for the sustainable development of China's energy supply and demand

5.1. Accelerate transformation of the mode of economic development

Based on China's current energy resources, it is very difficult to ease the prominent energy supply & demand contradiction relying solely on increasing energy supply. To propel three transitions in the mode of economic growth is imperative: the transition from relying mainly on investment and export to relying on a well-coordinated combination of consumption, investment and export, the transition from secondary industry serving as the major driving force to primary, secondary and tertiary industries jointly driving economic growth, and the transition from relying heavily on increased consumption of material resources to relying mainly on advances in science and technology, improvement in the quality of the workforce and innovation in management [24].

5.2. Strengthen energy-saving management system

To promote the sustainable development of China's energy supply and demand, independent innovation of science and technology should be strengthened, the energy conservation in areas of industry, construction and transportation should be implemented, and energy saving and support system should be perfected. First of all, the transformation of energy consumption idea should be guided, and the energy saving design standards and energy efficiency standard system should be perfected; second, the energy saving investment institution should be completed, and the government administration of energy saving service should be strengthened; in addition, finance and taxation policy should be improved to promote energy conservation and the enterprise energy audit system should be established. It is essential to enhance the comprehensive management level of energy-consumption and improve energy utilization efficiency.

5.3. Adopt globalized energy resource strategy

Take full advantage of the globalization of resources and give full play of "domestic and overseas resources and markets" to ensure the reliable support of China's energy support. The external dependence degree of crude oil and natural gas will run up to 54.8% and 30% respectively in 2020. Therefore, China should continue to implement the "going out" strategy, actively integrate into the international oil market and participate in the international oil and gas spot transactions and futures exchanges.

5.4. Enhance the exploitation and utilization of new energy

Optimize energy production and consumption structure. From the long-term and global perspective, China must strengthen the development of new energy and utilization level. At present, the structure based on fossil energy brings about huge environment, cost and efficiency problems [25,26]. The financial and technological input of new energy, especially clean and renewable energy should be enlarged; scientific and reasonable supporting policies should be established to promote the rapid development of new energy industry; the utilization proportion of new energy in the energy production & consumption structure should be progressively expanded.

5.5. Enhance energy transportation system

Strengthening the construction of energy transport system is crucial for the optimization of energy distribution. The construction of sending-out channel of large coal bases should be strengthened and the railway transport support ability should be improved; the safe and assorted pipelines of crude oil, petroleum and natural gas should be promptly constructed; the electricity output transmission channel from the national energy bases should be enhanced, extra-high voltage and high-capacity electricity transmission technologies should be paid great attention to [27,28], the distribution optimization ability of trans-regional resources of the large grid should be fully exerted, the proportion of electricity transmission in the output energy of the bases should be raised, and the simultaneous transmission of coal and electricity is finally achieved.

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